Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
An Inquiry Into the Commission's Policies	)	MM Docket No. 93-177
and Rules Regarding AM Radio Service	)	RM 7594
Directional Antenna Performance	)	
Verification	)	

JOINT WRITTEN EX PARTE FILING -- SUPPLEMENTAL COMMENTS OF BROADCASTERS, BROADCAST ENGINEERING CONSULTANTS, AND EQUIPMENT MANUFACTURERS

I. INTRODUCTION

In response to the Commission's *Notice of Proposed Rule Making* in this proceeding,[1] the National Association of Broadcasters (NAB)[2] hosted four *ad hoc* forums on AM directional antennas.[3] The purpose of these meetings was to provide an opportunity for experts in the science of AM directional antenna design and maintenance to share their ideas, experiences and concerns. As NAB noted in its initial comments,[4] the present AM directional antenna rules, adopted by the Commission in 1939, have served broadcasters well. Since that time, however, there have been great technological

[1] *Notice of Proposed Rule Making* (hereinafter "*Notice*"), MM Docket No. 93-177, RM-7594 (1999).

[2] NAB is a nonprofit incorporated association of radio and television stations and broadcasting networks. NAB serves and represents the American broadcasting industry.

[3] These forums were held at NAB headquarters on October 13, 1999, February 24, 2000, May 5, 2000 and June 23, 2000, respectively.

[4] Comments of NAB, MM Docket No. 93-177, November 9, 1999 at 1-2.

advancements in measuring and monitoring directional pattern stability factors. Modern computerized antenna pattern prediction methods have come into existence and, in the nearly seven years since the *Notice of Inquiry*[5] in this proceeding, software programs such as MININEC and NEC3 have been further developed. The industry has also gained considerable experience in employing these sophisticated tools for determining directional pattern stability.

At the October 13, 1999 meeting, there was consensus among the participants that computer modeling for method of moment analysis has advanced to the point of warranting the reduction in field measurements proposed by the Commission in the *Notice*. There was overwhelming consensus among the participants that further investigation on an industry-wide level on these issues would prove valuable in determining which types of antenna arrays can be accurately modeled on computers. In its initial comments, NAB requested a bifurcation of this proceeding to allow additional time for this further investigation.[6]

After several discussions with the Mass Media Bureau, however, NAB was informed that the Commission would not formally act on the bifurcation request. Instead, NAB was told that, due to scheduling of the Mass Media Bureau, there would be time to allow the industry to continue meeting and file supplemental comments. In addition, personnel from the Mass Media Bureau, at the industry's request, were present at each of the four *ad hoc* meetings. They provided valuable guidance as to the general parameters and policies of the Commission.

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[5] *Notice of Inquiry*, MM Docket No. 93-177 (1993).

[6] Comments of NAB at 2.

At the latter three *ad hoc* meetings, the discussion focused exclusively on computer modeling, and under what conditions it might be permitted to replace field measurements in the AM directional antenna proofing process. The companies that participated in these *ad hoc* meetings, including broadcasters, broadcast engineering consultants, and equipment manufacturers (hereinafter "Joint Commenters"), are together submitting these supplemental comments on this topic based on the conclusions they have drawn from the *ad hoc* forums.

II. BACKGROUND ON AM DIRECTIONAL ANTENNA COMPUTER MODELING

Conventional AM directional antennas consist of multiple vertical radiating elements, perpendicular to ground, strategically placed at specific distances from one another, and each fed with an AM signal of specific amplitude and phase so as to create destructive interference (minima) in certain directions and constructive interference (lobes) in other directions. Each of the vertical radiating elements in a directional antenna system can be thought of, by itself, as a monopole antenna perpendicular to a ground plane.

AM directional antenna computer modeling techniques were first developed for personal computers about twenty years ago; since then, they have been constantly refined. These techniques are based on Maxwell's equations, which relate to the current flowing in a wire to the electric and magnetic fields around the wire. These programs use the current flowing in each tower of an AM directional antenna (a known quantity that can be easily measured) to predict the electric and magnetic fields that will be produced by that tower.

One of the major advantages of computer modeling is that these programs can use the radiated field from each tower to accurately predict the current that will be induced by this field into the other towers. By doing this calculation for each tower in an AM directional array, and then combining the fields created by each tower, these programs can predict what the overall pattern from the AM antenna system will look like.

Figure 1
Stacked Wire Segments Create Model of AM Tower

Computer models for AM directional antenna systems do not treat each tower in the antenna system as a single wire, but rather as a series of connected wire segments (*see* Figure 1). The reason for this is that the phase of the current flowing in an AM tower is not sinusoidal throughout the tower, and breaking the tower into segments for modeling purposes makes it possible to more accurately model current flow by calculating the current parameters for each individual segment. The phase of the current at any particular point on the tower is dependent on three primary factors. These are:

1) the phase of the current being fed to the tower from the transmitter;

2) the distance between the point on the tower and the tower base; and

3) the current induced in the tower by the electromagnetic fields created by the other towers in the directional antenna system.

Figure 2 illustrates the three primary factors that determine the current flowing at any particular point in a tower of an AM directional array.

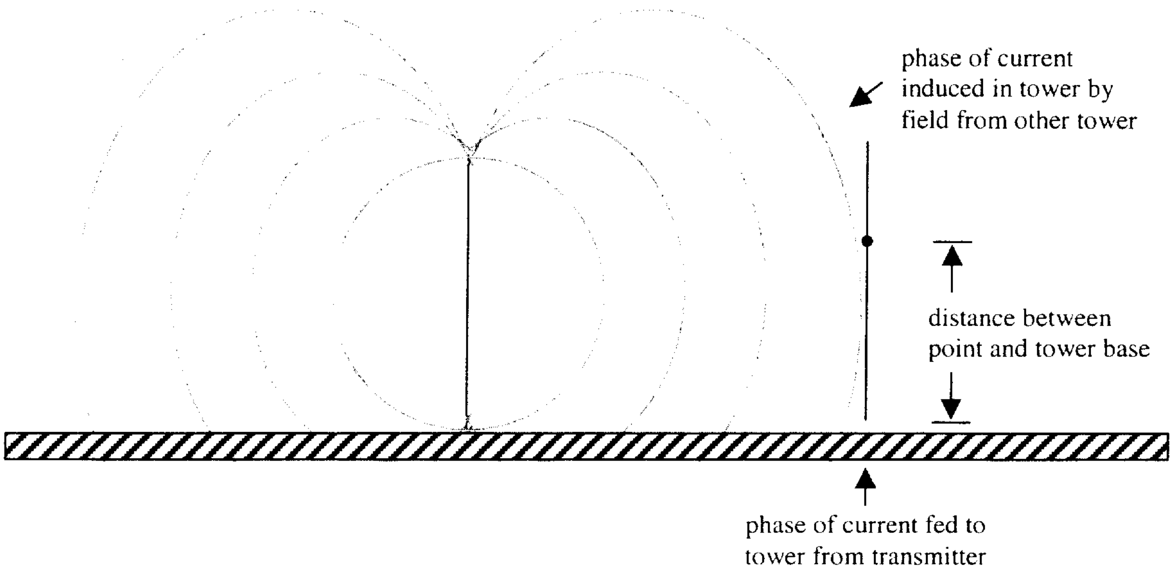

Figure 2
Three Primary Factors Determine Current Phase at Point on AM Tower

It is the ability to perform numerous complex computations to accurately predict the current induced in any given tower by the other towers in the array that enables today's computer modeling programs to predict the actual fields from each tower in the array with greater accuracy than ever before possible. Prior to the availability of these computer modeling techniques, it was necessary to assume that there was a sinusoidal distribution of current in each tower in order to keep the number of calculations necessary to predict the array's pattern at a manageable number. However, the current distribution in each tower is *not* sinusoidal, due mainly to the current induced in each tower by the fields from the other towers in the array. AM directional antenna modeling techniques coupled with the processing power of modern computers have made it possible to accurately predict the actual current distribution in each tower. This, in turn, has enabled the pattern produced by an AM array to be predicted with much greater accuracy.

III. LIMITATIONS OF AM DIRECTIONAL ANTENNA COMPUTER MODELING

Some of the participants at the *ad hoc* forums expressed the belief that all AM antennas are capable of being modeled with great accuracy. However, there was general agreement among all of the participants that, because very complex AM arrays require more expertise to accurately model, the Commission should initially limit the instances where computer modeling may replace field proofs to those situations where accurate computer models can be produced by all AM broadcast engineers. Much of the time at the *ad hoc* forums was spent identifying the criteria that, in the opinion of the experts present, would be characteristic of an array that could be modeled by any AM broadcast engineer at the current state of the art. These criteria are described in the attached Exhibit A.

In light of the Commission's ongoing transition to electronic filing, these criteria were put into a checklist format that could enable applicants to certify their eligibility for the use of computer modeling electronically. An item-by-item description of the reasoning behind each item in the checklist follows.

Criterion #1: The array should have six or fewer towers.

The more towers there are in an array, the more complicated it is to model, and the greater the possibility that errors might be introduced into the modeling process. Based on the cumulative experience of those present at the *ad hoc* forums, the Joint

Commenters feel that AM broadcast engineers should be capable of modeling arrays with up to six towers accurately. While many engineers would be capable of accurately modeling arrays with more towers, the Joint Commenters believe that, at least initially, modeling should be limited to arrays with no more than six towers in order to ensure accuracy. The Joint Commenters are hopeful that, after the Commission has some experience with permitting computer modeled data to replace field proofs, this issue may be revisited and the size of the arrays that the Commission permits to be modeled could be increased.

Criterion #2: Tower face widths should not exceed three electrical degrees.

Each AM tower is usually modeled as a straight wire,[7] and the computer model assumes that this wire's radius is very small with respect to both the wavelength of the AM signal and the wire length (tower height) so that any current flowing in the tower perpendicular to its height can be assumed to be negligible. Also, each wire (tower) is subdivided into short segments for analysis, and the radius of each segment must be small compared to the segment length so that the currents along each segment can be assumed to be directed along the axis of the segment, and not around its circumference. Thus, in order for the model to be accurate, the actual antenna system must conform to these assumptions. At the *ad hoc* forums, the experts present agreed that an appropriate method for ensuring computer model accuracy would be to limit the use of computer modeling to those arrays that do not have any towers with face widths greater than three electrical degrees.

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[7] Sometimes, multiple straight wires might be used. For example, a three-legged tower might be modeled as three vertical straight wires.

<u>Criterion #3: The difference in elevation between the lowest tower base in the array and the highest tower base in the array should be no greater than six electrical degrees.</u>

The Commission's model for predicting the coverage of an AM directional antenna system assumes that the bases of all of the towers in the array are at the same elevation.[8] In reality, the bases may not be at the same elevation. If they are not, it is important that the correct base heights be used in the computer model in order to accurately predict the pattern that will be produced by the array. If an array with base heights at different elevations were to be modeled as if the base heights were at the same elevation, then the current induced in each tower in the array by the other towers in the array would not be calculated correctly, and the computer model's prediction of the field produced by the array would not match real world conditions.

Generally, if the range of elevations of the base heights in the array is not too large, the actual pattern produced by the array can be expected to closely resemble the pattern that was presumed by the Commission's allocation criteria when the station was authorized. However, if the range of elevations of the base heights in the array is large, then the actual pattern produced by the array might differ more significantly from that which was predicted by the Commission's allocation criteria. In the latter situations, the potential for interference from the station being modeled to other stations is increased. Thus, it is critical that the station's emissions be closely monitored. The Joint Commenters believe that, for the time being, field proofs should still be required in such situations, and that the determining criterion should be whether or not the lowest and highest tower bases are separated vertically by more than six electrical degrees.

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[8] *See* 47 C.F.R. § 73.150.

Criterion #4: The difference between the lowest tower ground elevation and the highest tower ground elevation in the array should be no greater than six electrical degrees.

Those present at the *ad hoc* forums also felt that, for the same reasons arrays with tower bases that are separated vertically by more than six electrical degrees should continue to use field proofs at this time, so too should arrays with tower ground elevations that are separated vertically by more than six electrical degrees.

Criterion #5: There must be a post-construction surveyor's affidavit confirming that each tower in the array is located, relative to the array reference point, within 0.5 electrical degrees of the location specified on the station's construction permit.

Clearly, in order for an AM station's pattern to protect other AM stations from interference to the degree that the Commission expects, the station's towers must be located where the Commission specifies. To ensure that this is the case for antenna systems that are computer modeled, the Joint Commenters believe that there should be a *post-construction* surveyor's affidavit confirming that each tower in the array is located within 0.5 electrical degrees of where it is supposed to be. This tolerance ranges from 0.2 meters (0.8 feet) at 1700 kHz up to 0.8 meters (2.5 feet) at 540 kHz. The Joint Commenters propose this affidavit be kept on file at the station.

Criteria #6, #7 and #8: The RSS/RMS value for the array must be less than or equal to 2.00, 1.75 and 1.50 for arrays with no more than four towers, arrays with five towers and arrays with six towers, respectively.

Dividing the theoretical root-sum-square (RSS) value by the theoretical root-mean-square (RMS) value for the array provides an indication of the magnitude of the individual fields from the towers in the array compared to the total radiated field. If the resulting ratio is large (more than about 1.5) the array has the potential for instability, and may have a greater than desirable potential to interfere with other stations due to the magnitude of the values of the individual fields from the towers in the array which, by vector addition, sum to small values in the minima areas of the pattern. As a result, the Joint Commenters believe that limiting the use of computer modeling to those situations where the RSS/RMS ratio is less than or equal to 1.50 for six tower arrays, less than or equal to 1.75 for five tower arrays, and less than or equal to 2.00 for arrays with four or fewer towers would be appropriate.

Criterion #9: If current sampling loops are used to measure the current in each tower of the array, they must be installed in exactly the same configuration on each tower, at the height on each tower where the current will be at a minimum when the tower is detuned, and only on arrays whose towers have equal cross sections throughout their heights.

The Joint Commenters believe that sampling loops, base current sampling transformers, or base voltage samplers may be used to measure the current in an array for which computer modeling is permitted to replace field proofs. However, we recommend that certain conditions be placed on the use of each one of these devices to ensure that the current flowing in the array is measured accurately.

When sampling loops are used, they should be installed in exactly the same configuration on each tower. This ensures that the measured current ratios accurately reflect reality. Also, all of the towers in the array should have equal cross sections throughout their heights (the cross sections may vary with height, provided they all vary in the same manner) to eliminate the possibility that the actual current ratios between the towers might differ from the measured current ratios due to differing cross sections. Further, the sampling loops should be mounted at the height on each tower where the current will be at a minimum when the tower is detuned. This requirement will help to ensure that different people will reach the same measured results for the same array.

Criterion #10: In order for base current sampling transformers to be used to measure the current in each tower of the array, all of the towers in the array must be no more than 115 electrical degrees in height, or between 210 and 225 electrical degrees in height.

The Joint Commenters believe that base current sampling transformers should be permitted for measuring tower current ratios, but only for towers that are no more than 115 electrical degrees in height, or that are between 210 and 225 electrical degrees in height, due to concerns that the higher base impedances of other towers will result in base current readings that are not sufficiently accurate.

Criterion #11: In order for base voltage sampling systems to be used to determine the current in each tower of the array, all of the towers in the array must be between 105 and 220 electrical degrees tall.

The Joint Commenters believe that, while the low impedances of relatively short towers make base *current* sampling a suitable method for measuring tower current, they make *voltage* sampling somewhat unreliable as an accurate gauge. Conversely, while the higher base impedances of taller towers make current sampling unreliable, they are more suitable for voltage sampling. Thus, the Joint Commenters recommended computer modeling be permitted to replace field proofs for arrays that have base voltage sampling systems, provided that all of the towers in the array are at least 105, and no more than 220, electrical degrees in height.

Criterion #12: The sampling system transmission lines for each tower must have solid outer conductors, constant impedance throughout their lengths, and equal electrical lengths.

If computer modeling is allowed to replace field proofs for an array, the precision with which tower currents are sampled will become more important, since those samples will represent the basis for the measurements that, in essence, are replacing the field measurements. To ensure the integrity of the tower current sample as it travels from the towers back to the antenna monitor, the Joint Commenters recommend that the sampling system transmission lines be required to have solid outer conductors, constant impedances throughout their lengths, and equal electrical lengths. Splices should be permitted in these lines, provided that the electrical length remains the same, and the impedance does not change.

Criteria #13, #14, #15, #16 and #17: Restrictions on the presence of reradiating objects.

Conducting structures in the vicinity of an AM directional array receive energy from the antenna system and scatter or reradiate a portion of that energy. When the field strength incident on the conducting structure is of sufficient magnitude, and the structure is of sufficient height to be an efficient reradiator, unacceptable distortion of the directional field pattern can result. Because of the difficulty in accurately modeling structures such as office buildings, water towers, etc., that are often present in the vicinity of a directional array, these structures are not included in the computer modeling process. Because they are not modeled, but still can have an impact on a station's pattern, field proofs are still necessary when these structures are present. Thus, a criterion for eligibility must be established for use in determining when the presence of nearby reradiators should preclude the use of computer modeling as a replacement for field proofs.

The Joint Commenters believe that, for computer modeling to replace field proofs, an evaluation must be performed of the environment within ten wavelengths of the reference coordinates of the AM directional array. All manmade conducting structures having height greater than 0.075 wavelengths (at the AM station's frequency) must be included in this evaluation. Manmade conducting structures include:

communications towers, office and apartment buildings, water towers, highway lighting towers, smoke stacks containing conducting structure or lighting conduit, high tension power lines, elevated highway and railway bridges, and other structures that conduct current.

A. Criterion #13: High Tension Power Lines and Elevated Bridges

High-tension power lines and elevated bridges are large conducting structures, which can exhibit resonant characteristics at AM frequencies and present the potential for substantial reradiation. To be eligible for replacing field proofs with computer modeling, the Joint Commenters recommend that no high-tension power lines or elevated bridges with heights greater than 0.075 wavelengths be allowed within ten wavelengths of the reference coordinates of the directional array under study (Criterion #13).

B. Criteria #14, 16 and 17: Buildings, Towers, and other Conducting Structures

The magnitude of the reradiation from buildings, towers and other conducting structures is primarily a function of the field strength incident on the structure, the height of the structure, and, to a lesser extent, the radius or width of the structure. The impact of the reradiated field on the AM pattern can be evaluated by comparing the calculated reradiated Inverse Distance Field (IDF) at one kilometer with the standard pattern IDF at the azimuth of the absolute pattern minima. It is the judgment of the Joint Commenters that if the reradiated IDF from the conducting structure under study does not exceed 50 percent of the standard pattern IDF at the pattern absolute minimum then there is no significant impact to the directional field pattern. Based on this criterion and certain worst case assumptions with regard to radiation efficiency of typical conducting structures that might be encountered, the following eligibility criteria are recommended:

- There can be no conducting structures having heights greater than 0.075 wavelengths (at the AM station's frequency) within one wavelength of any active tower in the array (Criterion #14).

- Beyond one and out to ten wavelengths from the reference coordinates of the array, no conducting structure can exceed the height calculated using Equation 1 for thin structures (structures having height much greater than width) such as communications towers, light poles or smoke stacks; or Equation 2 for structures having large face widths such as multi-story office or apartment buildings. The equivalent radius defined later in these comments (*see* Criterion #18(b)) may be used as the radius of the reradiating structure for structures having rectangular or square cross-sections.

$$h \le 0.082\lambda \log\left[1.786\left(r/\lambda\right)\frac{E_{null}}{E_{IDF}}\right] - 5a_o + 0.248\lambda$$

$$For \quad h \ge 0.075\lambda \quad and \quad a_o \le 0.01\lambda$$

Equation 1 (Criterion #16)

or

$$h \le 0.09\lambda \log\left[1.786\left(r/\lambda\right)\frac{E_{null}}{E_{IDF}}\right] - 0.8w + 0.226\lambda$$

$$For \quad h \ge 0.075\lambda \quad and \quad 0.01\lambda \le w \le 0.1\lambda$$

Equation 2 (Criterion #17)

Where a_o = radius of reradiating structure (meters)
h = height of reradiating structure (meters)
λ = wavelength (meters)
w = building face width (meters)
E_{IDF} = standard pattern IDF at azimuth toward reradiating structure (maximum IDF over the arc subtended by the reradiating structure)
$E_{minimum}$ = standard pattern IDF at absolute pattern minimum
r = distance from array reference coordinates to reradiating structure (meters)

- If it can be determined that eligibility criteria #13 and #14 are met, and if there are no conducting structures between 1 and 10 wavelengths from the reference coordinates of the array which exceed the height defined by the simplified Equation 3 below, then a more detailed evaluation of each conducting structure using Equations 1 or 2 is not required.

$$h \leq 0.01(r) + 0.06\lambda$$

Equation 3 (Criterion #15)

Where:

r = distance from array reference coordinates to reradiating structure (meters)

C. Exemptions

The Joint Commenters believe that the presence of certain reradiating structures should *not* preclude the use of computer modeling in place of field proofs due to AM licensees' ability to monitor and control the reradiation from these structures. Specifically, the above formulas for determining the eligibility of AM arrays for computer modeling should not apply to structures that are controlled by the AM licensee, detuned to achieve zero field in the horizontal plane, and, if the reradiating structure is taller than 45 electrical degrees at the AM station's frequency, monitored to ensure that the detuning remains effective.

Criterion #18: To ensure that anyone who computer models a particular array reaches the same results, certain requirements need to be placed on the parameters used in the computer model.

For arrays where computer modeling might be permitted to replace field proofs it is important to prevent people from "playing games" with the computer model input parameters in order to alter the results (the predicted field). For example, one might try to vary the number of segments used to model the towers in an array in order to change the output. Or, one might make different assumptions about the thickness of the wire used in the computer model to represent an antenna. To prevent these sort of "games," the Joint Commenters strongly recommend various computer model input parameters be described with enough specificity by the Commission so as to ensure that anyone modeling a particular tower will be required to use the same input parameters. Therefore, we recommend the following conditions be placed on the application of the computer model:

a) The model must be version *.* of MININEC available at no charge from http://www.fcc.gov/__________;

b) The radius of the cylinder used to model each tower must be equal to 0.37 times the face width of a triangular tower, and 0.56 times the face width of a square tower, which are the radii necessary to create a cylinder with a cross-sectional area equal to that of a triangular or square tower;

c) The number of cylinder segments used to model each tower must be equal to the height of the tower, in electrical degrees, divided by ten and rounded up to the nearest multiple of three (tower height in feet x frequency in kHz ÷ 27,340 rounded up to the nearest multiple of three), OR, for towers no taller than 60 electrical degrees (164,040 ÷ frequency in kHz, feet), nine cylinder segments must be used to model each tower;

d) Each of the cylinder segments used to model each tower must be of equal length;

e) The modeled height of each tower in the array must be no greater than 110 percent, and no less than 100 percent, of the tower's physical height;

f) The series inductance used to model the hookup inductance between the output port of each antenna tuning unit and its associated tower and the internal inductance of the ground system must be no greater than 10 μH;

g) The shunt capacitance used to model capacitance effects at the base of each tower must be no greater than 150 pF plus the sum total of the manufacturer's stated, or separately measured, capacitances for any devices appearing across the tower base after the output port of its associated antenna tuning unit;

h) The tower impedance values to be used in the model must be the measured impedance values at the output port of each tower's tuning unit (at the point where its base current or voltage sampling device, if employed, is installed) while all of the other towers in the array are shorted from their measurement points to the reference grounds of their output ports. The measured tower impedance values must be within ±4.0 percent and 2 Ω of those used in the model, for both resistance and reactance; and

i) All reradiating structures controlled by the AM licensee and taller than 22,500/f(kHz) meters [73,819/f(kHz) feet] (0.075 wavelengths) within 300,000/f(kHz) meters [984,252/f(kHz) feet] (one wavelength) of the reference coordinates of the array; and all reradiating objects controlled by the AM licensee that lie beyond one, and out to ten wavelengths from the reference coordinates of the array that do *not* comply with the following formula:

$$h \leq 0.01(r) + 0.06\lambda$$

Where h = height of reradiating structure (meters)
λ = wavelength of AM station (meters)
r = distance from array reference coordinates to reradiating structure (meters)

must be detuned by the AM licensee so there is zero field in the horizontal plane and, if the height of the reradiating structure exceeds 37,500/f(kHz) meters [123,031/f(kHz) feet] (45 electrical degrees) at the AM frequency, it must be monitored by the AM licensee to ensure that the detuning remains effective.

IV. CONCLUSION

For the reasons stated above, the Joint Commenters recommend that, subject to the conditions outlined in these supplemental comments, computer modeling should be permitted to replace field proofs for certain AM arrays. We also recommend that the checklist outlined in Exhibit A be used to determine the eligibility of an array for computer modeling, which could easily be incorporated into the Commission's electronic filing system.

Respectfully submitted,

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